Technical Supplement 3B

Using Aerial Videography and GIS for Stream Channel Stabilization in the Deep Loess Region of Western Iowa

Issued August 2007

Cover photo: Channel stabilization in western Iowa begins with an understanding of streambed gradients and their natural controls and causes of instability. Channel degradation or incision is widespread in this area. Soils in the deep loess region of the Mississippi River Basin are some of the most highly erosive in the country.

Advisory Note

Techniques and approaches contained in this handbook are not all-inclusive, nor universally applicable. Designing stream restorations requires appropriate training and experience, especially to identify conditions where various approaches, tools, and techniques are most applicable, as well as their limitations for design. Note also that product names are included only to show type and availability and do not constitute endorsement for their specific use.

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Abstract

This technical supplement presents an example of using an aerial assessment and classification of streams in the deep loess region of western Iowa. This is a large-scale effort directed by the Hungry Canyons Alliance involving approximately 5,250 miles of stream in 22 western Iowa counties. This effort has determined areas of active stream erosion and the impact streambed stabilization structures have had on controlling stream degradation. The stream assessment consisted of flying along streams in a small helicopter videotaping the stream channel and recording positions with a global positioning system receiver. Streams were classified based on a six-stage channel evolution model to describe the dominant channel processes occurring along stream reaches. Streams across the region in 1993 and 1994, and in a smaller area in 2000, were similarly classified.

The comparison of the recent classification to those of the past has allowed the researchers in this study to describe how stream stabilization structures have impacted the streams and make predictions as to where future stream erosion will occur. The data has also been used to mathematically model channel evolution in the region.

The purpose of Hungry Canyons Alliance (HCA) is to focus attention on the problems and develop solutions related to stream channel degradation in 22 counties of western Iowa with deep loess soils. The HCA provides cost share to counties to build streambed stabilization structures, building about 20 structures per year. To date, HCA structures protect 195 bridges; numerous utility lines including electric, phone, gas, sewer, water lines; and an estimated 830 acres (336 ha) of farmland, equivalent to stopping 11.3 million tons (10.25 million metric tons) of sediment from being swept away into the Missouri River and Mississippi River systems.

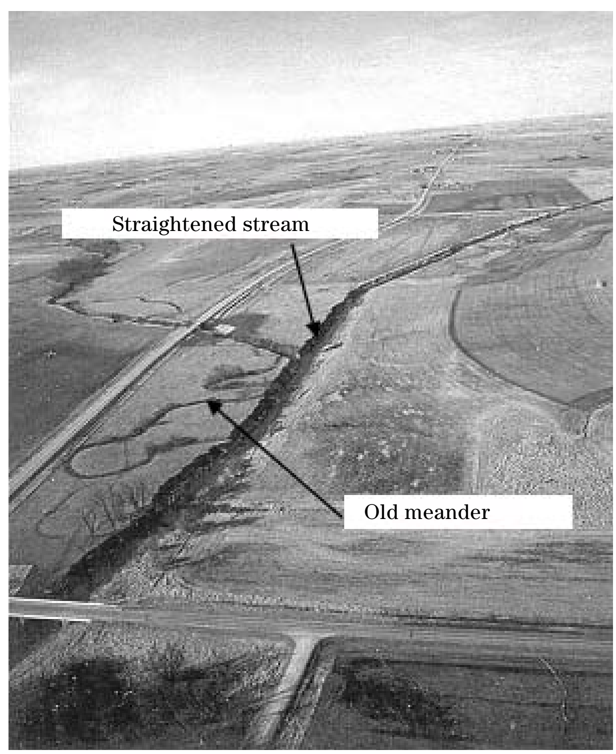
However, HCA members need to know where the areas of active stream erosion are to wisely locate structure sites. To do this, an aerial assessment of streams in western Iowa was performed, and streams were classified based on the channel evolution model.

Introduction

In western Iowa, 22 counties contain deposits of loess ranging from 13 feet (3.96 m) to more than 200 feet (60.96 m) deep. Loess is highly erodible and susceptible to stream channel erosion and degradation. It is estimated that stream channel downcutting and widening in western Iowa has caused $1.1 billion in damage to bridge and utility infrastructure (Hadish et al. 1994). Stream degradation has also eroded thousands of acres of valuable farmland, increased stream sediment loads, and decreased water quality.

Stream channel dredging, straightening, and land use changes since the early 1900s have caused many problems. After straightening, the streambed is steeper because the stream still had the same amount of fall per mile, yet there was now a shorter distance over which that fall occurred. The steeper slope increased water velocities. To reduce the water velocity, streams either had to meander or downcut. Due to the high erodibility of loess soils, the streams began downcutting, causing accelerated soil erosion in western Iowa (fig. TS3B–1).

Figure TS3B–1 Straightened versus meandering stream (Walnut Creek, Pottawattamie County, IA)



As the streambed downcuts, it destabilizes bridge pilings (fig. TS3B–2), and the vertical streambanks will slump to a more stable slope, in effect widening the stream and necessitating longer bridges.

Nickpoints, which are naturally occurring overfalls (fig. TS3B–3), will continue to erode and advance upstream, eventually affecting the entire watershed. Bed degradation of stream channels will force the channel's tributaries to also adjust to the lowered base level, often initiating gully formation where no channel had previously existed.

Streambed stabilization is the key to preventing further erosion and protecting infrastructure (fig. TS3B–4). After the stream downcut 6 feet in 7 years, the bank stabilization was left high and dry. Dams or weirs at regular intervals will help streams stabilize by changing their profile from a steep incline to a stable stair-step pattern. Structures normally have a raised weir section, like a low-head dam. Most structures use steel sheet pile driven into the streambed 20 to 25 feet (6.1–7.6 m) and riprap to protect the banks (fig. TS3B–5).

Figure TS3B–2 Bridge endangered by exhumation of pilings

Figure TS3B–3 Nickpoint eroding headward

Figure TS3B–4 An NRCS bank stabilization site that did not include streambed stabilization, (Page County, IA)

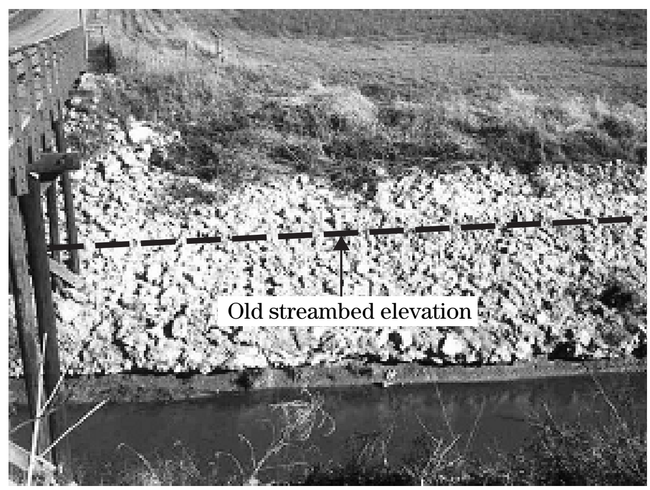


Figure TS3B–5 HCA steel sheet pile weir with riprap and cement grout that protects a large sewer main for the City of Denison, IA

Streambed stabilization structures have many benefits. They decrease the slope of the streambed, reducing water velocities. They prevent further downcutting, protecting farmland, bridge pilings, and utility lines from future erosion. They create an upstream back-water condition which allows sediment to settle out, reducing sediment loads and improving water quality. The backed-up water often helps to protect bridge pil-ings by submerging them.

Previous research

A six-stage channel evolution model (fig. TS3B–6, developed by Simon and Hupp (1986), was used to describe the dominant channel processes occurring along stream reaches.

An aerial reconnaissance of streams in 18 western Iowa counties was conducted in 1993 and 1994 by the HCA. They were flown during the spring to prevent tree cover and other vegetation and snow and ice from obscuring the view of the channels (Hadish 1997). The stream channels were recorded through the door of a low-flying helicopter by a hand-held video camera while a microphone recorded a narration onto video tapes. This narration described location information and other observations. The video focused on the streambed, streambanks, and the flood plain, along with other features like gullies, nickpoints, and grade control structures.

In conjunction with a set of manually transcribed notes, the videotape and narration was used to classify streams by Simon's six-stage channel evolution model. Classified stream reach locations were transferred to USGS 1:100,000 scale topographic base maps by hand. These hard copy maps were then converted to a digital data set using the Geographic Resources Analysis Sup-port System (GRASS) geographic information system (GIS) software package. GRASS GIS is an open source free software GIS that is largely command line driven. In 2000, the NRCS reclassified streams in four counties and classified streams in two additional counties using the same process.

In the 1993 to 1994 study, 107 streams covering 1,540 miles (2,478 km) were videotaped. More than 90 per-cent of the study area at that time was unstable, in stages 2, 3, 4, and 5, with the greatest amount (55.9 percent) in stage 4 (Hadish et al. 1994). Stage 5 was concentrated in the downstream portions of larger drainages, whereas stage 3 reaches occurred in the upper reaches of main streams and on small tributar-ies. The data supported the notion of a recovery pro-cess, described by the channel evolution model, where degradation progresses from the lower to the upper stream reaches followed by aggradation (Hadish 1997).

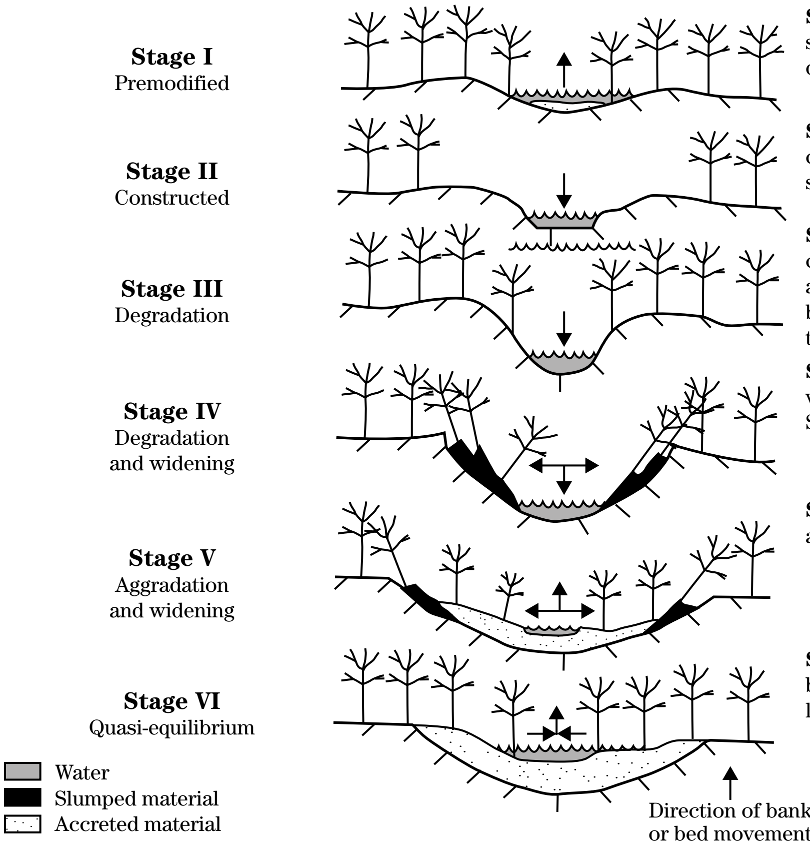
Methods

Many issues led the HCA to undertake another stream classification. First, the 1993 to 1994 data was largely outdated and not very helpful in streambed stabiliza-tion project planning. Second, it is still important to determine where streams are actively eroding and make predictions as to where future erosion will occur. Third, the HCA wanted to determine the im-pact of streambed stabilization structures on stream degradation. Fourth, with two sets of data, channel evolution in the region can be modeled by comparing the progression of erosion between flights. Finally, current stream videos and maps can be used by county engineers and NRCS district offices for other purposes such as county infrastructure inspections, land use planning and zoning, and conservation practice evalu-ations.

To update the stream classification, the decision was made to videotape those streams that were previously flown, had grade control structures on them, had drainage areas of more than 10 square miles, or were known to be experiencing streambed degradation. The stream classification began in the spring of 2002 and continued during the fall of 2002 and spring of 2003, when flying ended due to foliage or inclement weather.

The same basic process was again used to classify streams, but there were significant changes due to technological advances. Videotaping was done through the open door of a small helicopter with a hand-held digital video camera while a global positioning system (GPS) receiver recorded the position. The Video Map-ping System (VMS), engineered by Red Hen Systems of Fort Collins, Colorado, integrates video and still images with simultaneous location information re-corded by the GPS. The GPS signal is stored on one of the audio tracks of the videocassette. For added error

Figure TS3B–6 Six-stage channel evolution model



Stage 1: Includes streams that have not been modified and tend to be very stable. These streams tend to meander across their flood plain and have a dense vegetative cover on the banks down to the low-flow line of the channel.

Stage 2: Associated with streams recently modified or channeled by construction. Degradation at this stage depends upon such characteristics as streambed slope, angle of the banks, and cross-sectional area.

Stage 3: Degradation occurs most rapidly in the streambed. The increased channel slope increases the flow velocity, which causes the channel to deepen and its bank slopes to become steeper. As the channel downcuts, the toe of bank slopes are undercut, and bank failures will occur. Full-scale degradation takes place during this stage

Stage 4: Evident by channel widening. Mass erosion of bank soils and vegetation is predominant, creating a scalloped appearance in the banks. Streambed degradation slows during this stage

Stage 5: The bed of the channel begins to stabilize; bank failures decrease and re-vegetation occurs. The height and slope of the banks is reduced.

Stage 6: Channels show re-vegetation as it becomes increasingly stable and bank widening stops. Vegetation may extend in a dense cover up the sides-lopes reduction, in case the GPS unit stopped working, notations on county maps and a journal were kept to note locations, dates visited, and keyed to the corresponding videocassettes on which that information had been recorded. The video was brought to the office where it was indexed by VMS, which associates a segment of videotape with the recorded GPS locations and translates this information between the GPS receiver, camcorder, and computer.

Once a tape was indexed, it was ready for classification, where attributes such as the six-stage channel evolution model were added to the information collected by GPS by examining the videotaped segment and applying a value to each stream reach. When that process is completed, the data are then exported out of the VMS software package as an ESRI formatted shapefile. The shapefiles were then brought into ESRIs ArcGIS, a menu and button driven software package, where further data manipulation such as overlaying the data with previously collected data sets and other spatially referenced information was performed.

One of the finished products that will be important to the overall impact of the project is the creation of DVDs for distribution to project partners. After the videotape was analyzed, a set of DVDs showing streams in their county was made available to county engineers and NRCS district offices to use in stream channel stabilization project planning.

Results

The stream reaches that were flown in the spring and fall of 2002 and the spring of 2003 are shown in figure TS3B–7. Also shown in figure TS3B–7 is the 22-county HCA region, loess thickness, and locations of known grade control structures (207 HCA, 300 EWP, 6 Iowa DOT, and 39 landowner-installed grade control structures).

To determine the progression of erosion through time and the impact streambed stabilization structures have had on controlling stream degradation, two segments of stream that were classified in 1994 and again in 2002 are shown for comparison in figure TS3B–8. In 1994, Graybill and Jordan Creeks in Pottawattamie County were predominately stage 4, with stage 3 farther upstream in the watersheds. Only two structures had been built on these streams at that time. The arrow points to a bridge where 23 feet (7 m) of degradation was recorded between 1972 and 1993. By 2002, 14 additional structures had been built on these two creeks. The streams have become less erosive and more stable, with the average stream at stage 5.

Degradation has migrated about 5 miles (8 km) upstream with stages 3 and 4 occurring only near the headwaters of the streams.

Conclusion

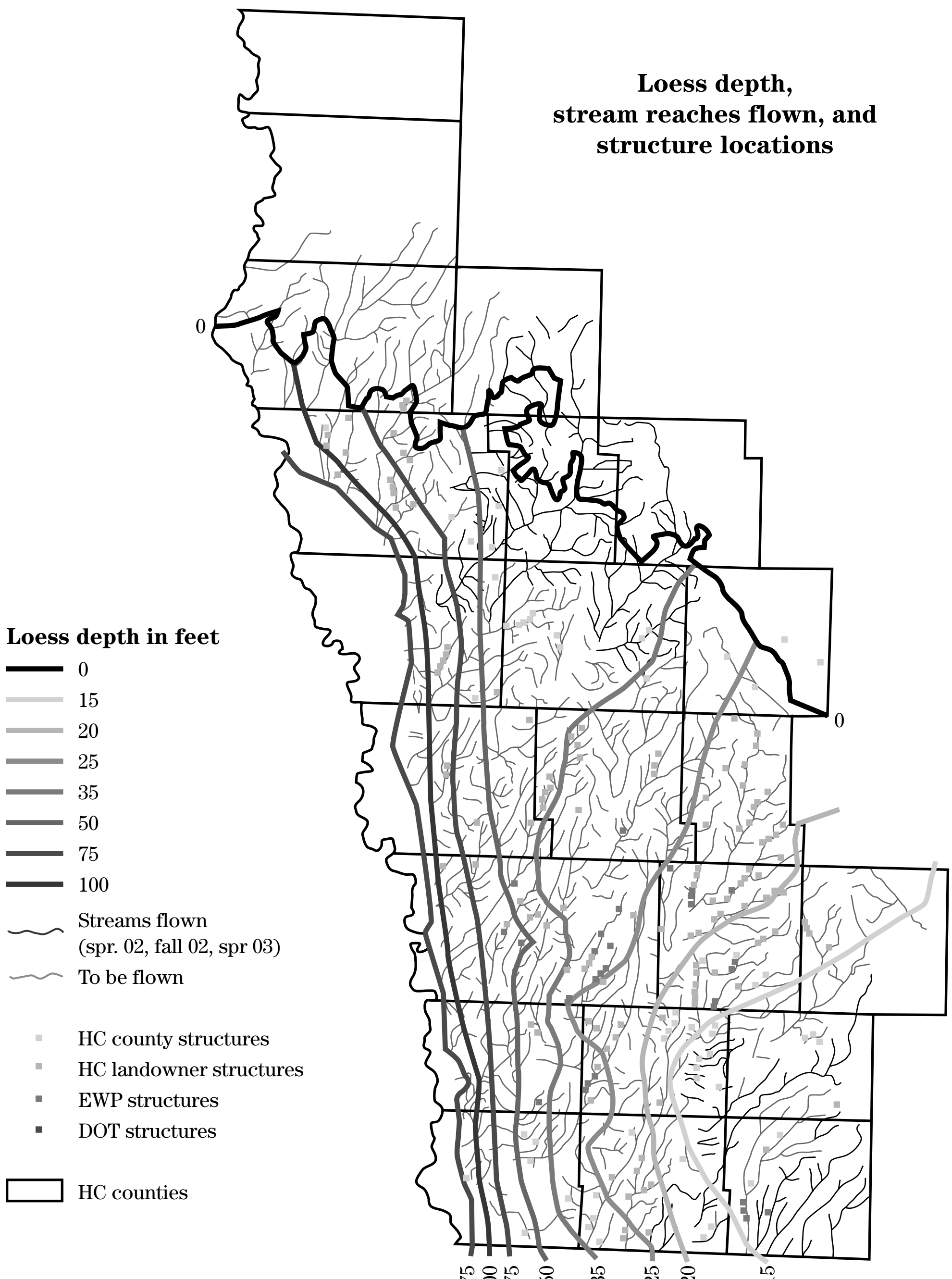
The use of aerial videography and GIS has proven to be a rapid and effective technique for rapidly assessing streams.

In the subject study, degradation does not appear to extend into areas where there is no loess soil cover, that is, beyond the loess-till boundary (line of 0 loess depth) in the northern half of western Iowa. Degradation, particularly gully erosion, becomes more pronounced in areas where loess soils are thickest.

Most large streams (those streams with a watershed greater than 70 square miles (181 km^2)) are no longer degrading, but aggrading. Many show evidence of deep incision in the past; however, they have filled with sediment eroded from upstream as degradation has moved upstream. This recovery process was also noted by Hadish (1997). The likelihood of active degradation becomes greater with distance north-northeast away from the Missouri River because many streams near the river experienced degradation first as degradation has migrated upstream. They have since become stabilized by the influx of sediment from upstream. Degradation only occurs where streams have been channelized downstream. The closer a stream reach is to the original channelization, the greater the degradation that has occurred on that stream reach.

Grade control structures appear to have helped stabilize large stretches of stream. Streambeds up to 1 mile (1.6 km) upstream from the structures have been stabilized (fig. TS3B–8). For example, the rapid stabilization of Graybill and Jordan Creeks is largely due to the construction of grade control structures at regular intervals.

Figure TS3B–7 Stream reaches flown and classified in 2002 and 2003, grade control structure locations, loess depth, and 22 western Iowa counties in the HCA



Only an example, not accurate

Figure TS3B–8 Comparison of two classified stream reaches on Graybill and Jordan Creeks in 1994 and 2002